

# BRAZOS RIVER WATERSHED, TEXAS

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## LETTER

FROM

ACTING SECRETARY  
DEPARTMENT OF AGRICULTURE

TRANSMITTING

A SURVEY REPORT DATED JANUARY 1951, TOGETHER  
WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS,  
OF THE BRAZOS RIVER WATERSHED IN TEXAS, MADE  
UNDER THE PROVISIONS OF THE FLOOD CONTROL  
ACT APPROVED JUNE 22, 1936, AS AMENDED AND  
SUPPLEMENTED



MARCH 20, 1952.—Referred to the Committee on Public Works and  
ordered to be printed with illustrations

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UNITED STATES  
GOVERNMENT PRINTING OFFICE  
WASHINGTON : 1952

BRASOS RIVER WATERSHED, TEXAS

LETTER

1907

ACTING SECRETARY

DEPARTMENT OF AGRICULTURE

WASHINGTON

A FIELD REPORT DATED JANUARY 1907 TOGETHER  
WITH ACCOUNTS OF THE BRASOS RIVER WATERSHED  
OF THE BRASOS RIVER WATERSHED IN TEXAS MADE  
UNDER THE PROVISIONS OF THE FLOOD CONTROL  
ACT APPROVED JUNE 20, 1906 AS AMENDED AND  
SUPPLEMENTED



MAY 20 1907 - Forwarded to the Committee on Public Works and  
ordered to be printed with illustrations

UNITED STATES  
GOVERNMENT PRINTING OFFICE  
WASHINGTON: 1907

## LETTER OF TRANSMITTAL

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DEPARTMENT OF AGRICULTURE,  
OFFICE OF THE SECRETARY,  
*Washington, March 10, 1952.*

THE SPEAKER, HOUSE OF REPRESENTATIVES.

DEAR MR. SPEAKER: I am submitting herewith a survey report, dated January 1951, together with accompanying papers and illustrations, of the Brazos River watershed in Texas, made under the provisions of the Flood Control Act approved June 22, 1936, as amended and supplemented.

I recommend that the Secretary of Agriculture be authorized to carry out the program of runoff and water-flow retardation and soil erosion prevention proposed in this report.

The proposed report was sent to the Governor of Texas and interested Federal agencies, and the comments received are enclosed.

The Department of Agriculture and the Department of the Army, Corps of Engineers, are now engaged in joint studies of floodwater retarding structures and floodway and channel improvements to correlate the proposed programs of the two Departments within the Brazos River watershed. These programs will be correlated to the fullest extent possible prior to the initiation of construction of the structures or improvements involved.

The Bureau of the Budget, in its letter of February 25, 1952, advises that there is no objection to the submission of this report to the Congress. The Bureau further states that it is in agreement with the objective contemplated in the report of carrying out measures designed to retard floods and prevent soil erosion, and that this objective is particularly desirable from the point of view of coordination of upstream measures with the flood control programs of the Corps of Engineers. A copy of the letter from the Bureau of the Budget is enclosed.

Sincerely,

K. T. HUTCHINSON,  
*Acting Secretary.*

## THEORY OF THE EARTH

BY J. H. VAN DIJK

Professor of Geology, University of Amsterdam, The Netherlands

The theory of the earth is a branch of geology which deals with the origin and development of the earth and its various parts. It is a science which seeks to explain the processes which have shaped the earth and its features. The theory of the earth is based on the study of the earth's history and its various parts. It is a science which seeks to explain the processes which have shaped the earth and its features. The theory of the earth is based on the study of the earth's history and its various parts. It is a science which seeks to explain the processes which have shaped the earth and its features.

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## BRAZOS RIVER WATERSHED, TEXAS

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### LETTER FROM THE BUREAU OF THE BUDGET TO THE SECRETARY OF AGRICULTURE

EXECUTIVE OFFICE OF THE PRESIDENT,  
BUREAU OF THE BUDGET,  
*Washington, D. C., January 25, 1952.*

The honorable the SECRETARY OF AGRICULTURE.

MY DEAR MR. SECRETARY: This is in response to Acting Budget Officer John Wells' letter of February 5, 1952, concerning the relationship to the President's program of the proposals contained in your Department's report dated January 1951, entitled "Survey Report, Brazos River Watershed, Texas." The proposals in this report include those contained in interim reports on two tributaries of the Brazos River—the Little and Bosque watersheds—which were submitted by your Department on January 31, 1951.

Floodwater, sediment, and indirect damages occurring in the Brazos River watershed are estimated to average \$14,550,000 annually. The principal losses, estimated to average \$10,304,000 annually, are caused by flooding of agricultural crops. Floods also cause damage to roads, buildings, and other property, while sediment damages occur to water supplies, reservoirs, and drainage channels.

It is proposed to alleviate these damages and to realize extensive associated benefits by installing a number of interrelated and interdependent soil and water conservation and control measures or groups of measures, mostly vegetative in character, during a 15-year period. These measures, applied in proper combination with other soil and water conservation practices and measures, would constitute a basic system of soil and water conservation in accordance with needs and capabilities of the land in the Brazos River watershed. Educational assistance and technical services are also recommended as a part of the proposed program.

The estimated total cost of the recommended program, based on 1949 prices, is \$109,065,000. The Federal Government would be expected to expend \$69,084,000 of the total cost; non-Federal public agencies would expend \$9,578,000; and private interests would contribute \$30,403,000 or its equivalent in labor, materials, equipment, easements, and other assistance in lieu of cash payments. Operation and maintenance of the recommended works of improvement are estimated to cost \$9,552,000 annually, of which \$7,500 would be paid by the Federal Government for operating and maintaining a system of fire protection, and \$9,547,500 or its equivalent would be borne by local interests.

It is estimated that the recommended watershed program, if installed as planned and maintained adequately, will yield average annual benefits evaluated at \$31,035,000. These benefits may be grouped under

two categories: Flood-control benefits and conservation benefits. The flood-control benefits, which are derived chiefly from channel improvement and stream-bank stabilization, consist of floodwater damage reductions to crops and pastures, roads and other property, and sediment damage reductions resulting in a lowering of the cost of treating public water supplies and maintaining reservoirs and drainage channels, and seem to be incidental to the over-all conservation benefits of the recommended program. It is noted that the average annual floodwater, sediment, and indirect damage of \$14,550,000 would be reduced by \$5,690,000, or about 39 percent. The conservation benefits of \$25,345,000 would result mainly from the provision of farm waterways, terraces, pasture development, and other conservation measures.

The total average annual costs are estimated at \$12,796,827. Since prices are expected to vary during the 15-year installation period, both benefits and costs were adjusted to anticipate future price levels by applying indexes provided by the Bureau of Agricultural Economics. The effect of this adjustment or alternate evaluation is to reduce monetary values of both benefits and costs. Thus, the average annual benefits are adjusted to \$18,968,453 and the costs, on the same basis, to \$8,324,345. This adjustment results in a revised benefit-cost ratio of 2.28 to 1 for the recommended program.

The report has been reviewed by the Governor of Texas and by the several concerned Federal agencies in accordance with policies and procedures for distribution and coordination of reports as adopted by the Federal Inter-Agency River Basin Committee. The views expressed are generally favorable to the proposed program. However, Lt. Gen. Lewis A. Pick, Chief of Engineers, recommends that, prior to authorization, a joint study of the proposed floodwater retarding structures and channel improvements be made by the Department of Agriculture and the Corps of Engineers. It is understood that arrangements to begin such a joint study have already been made.

The work envisioned in the report constitutes predominantly open-land, farm, and woodland improvement measures which will produce very high conservation benefits, accruing mainly to landowners and farm operators in the form of increased returns due to improved practices. The program recommended appears to be largely an intensification, acceleration, and adaptation of soil and water conservation activities already in progress under going programs of the Department of Agriculture. These include such programs as the conservation and use program, authorized by the Soil Conservation and Domestic Allotment Act, approved February 29, 1936, as amended; the Soil Conservation Service's program of assistance to districts and other cooperators, authorized by the act of April 27, 1935; and the State and private forestry cooperation, pursuant to the act of August 25, 1950, sections 1 through 5 of the act of June 7, 1924, and acts supplementary thereto.

The Bureau of the Budget is in agreement with the objective contemplated in the report of accelerating land-treatment measures and installing structural measures designed to retard floods and prevent soil erosion. This objective is particularly desirable from the point of view of coordination of upstream measures with the flood-control programs of the Corps of Engineers.

The measures contemplated to implement the proposed program might be grouped into two broad categories: Land-treatment measures and structural measures. The Bureau of the Budget is of the opinion that installation of the structural measures (shown in table 2, p. 12, of the report as farm and group waterways, gully stabilization, floodwater retarding structures, and floodway and channel improvement) should properly be authorized under the flood control act, as amended and supplemented. The Bureau also believes that the land-treatment measures set forth in the report, since they are largely an acceleration of existing programs of the Department of Agriculture, should be financed under appropriations other than that for the flood control act. This would avoid confusion in the presentation of the Department's budgetary program, since many of the current land-treatment programs of the Department have the objective of runoff and water-flow retardation and the prevention of soil erosion. To the extent that the acceleration of land-treatment measures under existing authorities is not possible, we urge that adequate authorities for such acceleration be sought through amendment of those basic authorities.

Your staff, on the other hand, believes that the Department cannot properly meet its responsibilities under the Flood Control Act unless the full program envisioned in the report is authorized under that act. Your representatives, however, agreed that appropriations for land-treatment phases implementing the program recommended in the report, upon approval by the Congress generally on the basis as submitted, would be sought as additions to going program appropriations of the agencies carrying on the work. Funds for structural works or measures would still be requested under the appropriation "Flood control." The total obligations for land-treatment and structural measures in each authorized flood control project area could, of course, be shown in a summary table to be presented in the program and performance section of the annual budget document.

Subject to the above understanding as to the method of presenting the budget for flood-control programs, there would be no objection to the submission of the proposed Brazos River watershed flood control survey report to the Congress. In the event the report or any modification thereof is approved by the Congress, submission of requests for appropriations must be justified in accordance with the policy set forth in the President's letter of July 21, 1950, which directed that all civil public works be considered with the objective, as far as practicable, of deferring, curtailing, or slowing down those projects which do not directly contribute to national defense or to civilian requirements essential to the changed international situation, or as may later be modified.

In submitting the Department's report to the Congress, it will be appreciated if you include a copy of this letter.

Sincerely yours,

ELMER B. STAATS,  
*Assistant Director.*

## LETTER FROM THE CHIEF OF ENGINEERS TO THE SECRETARY OF AGRICULTURE

DEPARTMENT OF THE ARMY,  
OFFICE OF THE CHIEF OF ENGINEERS,  
*Washington, September 25, 1951.*

The honorable the SECRETARY OF AGRICULTURE,  
*Washington, D. C.*

DEAR MR. SECRETARY: Reference is made to the report of the Department of Agriculture on the Brazos River Basin of Texas which has been transmitted to this Office for comment.

Your report recommends a program of watershed improvement and of flood control for the Brazos River Basin, to be installed over a 15-year period. The total cost of this program is estimated at \$109,065,000. Of this amount the Federal Government would expend \$69,084,000; other public agencies, \$9,578,000; and private interests would contribute \$30,403,000.

The program divides essentially into two major and distinct but related classes of improvement. The first of these for land treatment, soil-erosion prevention, and runoff and water-flow retardation includes terraces, field diversions, cover cropping, establishment of new grass land, fire protection, and improved land-management practices. It also includes the shaping and stabilizing by vegetative control of about 5,200 miles of farm and group waterways; and gully stabilization on over 2,300 miles of channels. I am unable to comment regarding the engineering or economics of this important phase of your recommended program, but consider that measures of this kind would be of value in restoring, improving, and preserving the lands of the watershed and that, while these measures alone will not control major floods, they would retard runoff and water flow and aid in holding water on the land, and would undoubtedly complement the projects and plans of the Corps of Engineers for flood control and water conservation in the Brazos Basin.

The second class of improvements in your recommended program, involving about 41 percent of the estimated cost, includes some 555 floodwater retarding reservoirs to be formed by construction of earth dams with substantial channel and floodway improvements on about 81 miles of tributary streams. I am particularly concerned with this phase because it is closely interrelated with the Federal program authorized and recommended for flood control in the Brazos Basin, under the jurisdiction of the Corps of Engineers.

I understand from your report and from the consultation between our agencies which has taken place at field level, that a "sampling process" and general plans and estimates have been used by your Department in setting up this large system of flood retarding reservoirs and in preparing cost estimates and computations of benefits. This procedure appears necessary to preparation of programs and recommendations for watershed improvement measures such as those of the first class referred to in this letter, and perhaps in some instances smaller water-flow retarding structures. I do not believe, however, that this method of investigation and planning is adequate to develop the engineering plans, estimates of cost, and data on economic justification, which we consider necessary as a basis for recommendation



for dams of moderate size, or for a group of small dams which would control a substantial part of the flood producing area of a basin. This method is reflected in a lack of specific data in the report, which does not permit me to comment specifically on the engineering adequacy, effectiveness, cost and economics of the works recommended. I have, however, certain general observations to make.

The proposal to build over 500 small reservoirs on smaller tributaries of the Brazos, would in effect establish a system of temporary storage of flows from an area of over 4,000 square miles, or about one-third of the subwatershed areas for which control is planned. A system of this kind would have a serious impact on downstream flood problems, and upon the effectiveness and security of downstream works for flood control and water conservation. Careful flood studies and flood routings would be necessary to establish the cumulative effect of these retarding reservoirs on floods in the main river valleys. Your report indicates that the small reservoirs you propose would provide a degree of flood protection only in the small stream valleys immediately below the structures. Our studies indicate that they will not protect main stream valleys from large floods, and may result in aggravated flood situations in downstream areas.

It is not possible to determine definitely whether the system of small reservoirs would operate successfully under conditions of heavy precipitation over the entire basin which would cause a major flood. The report does not give information on the location of structures and heights of dams, to indicate the extent to which failure under major flood conditions might involve hazard to life or serious property damage. Such possibilities, however, may be involved as the report does claim substantial monetary benefits for prevention of flood damage and states that "there will be unevaluated benefits such as prevention of loss of life." Consequently, some of the dams must lie above developed and settled areas, and at least the larger ones should be highly dependable structures.

The costs of the reservoirs can be examined only generally, but on an acre-foot basis they appear to be much less than experienced costs of similar storage as given in your report; and the costs seem low on the basis of our experience. While the unit of flood damages per acre for cropland used in your report seems reasonable, sufficient data is not available in the report to check the frequency and magnitude of floods used in the report as a basis for estimated damages to be prevented and consequent benefits.

It is obvious that many of these 555 dams would be small and would be essentially water-flow retarding structures without appreciable control of major floods. In other cases the dams would probably reach heights and provide storage capacities which would place them in the category of flood control projects of the type for which the Corps of Engineers is normally responsible. The data given does not permit a division of the dams between these two groups. It appears, however, that in this part of your proposed program, and in the larger channel improvements proposed, there is a zone of mutual interest which requires the further coordinated attention of our two agencies.

I appreciate that it is the intention of your Department to investigate these matters and prepare the necessary detailed plans for these



reservoirs and channel improvements after authorization. I feel, however, that this phase of your program for the Brazos Basin is of major importance; that serious questions of engineering adequacy, effect, and economics have not been answered; and that the correlation of this part of your program with other plans for flood control and water conservation in the basin is so necessary, that this should be accomplished prior to authorization by Congress. I am, therefore, unable to concur with a recommendation for authorization of this part of your program on the basis of existing studies and consider that, with respect to the reservoirs and channel improvements, your report should recommend that they be made the basis of a further joint investigation by the Corps of Engineers and the Department of Agriculture.

It does not appear to me that there would be any material loss of time or effort in the further joint study I propose for the second class of work set forth in your program. Provision of the watershed improvement phase of your program seems to be the obvious first step and, as this by itself is a program of considerable magnitude, it is probable that further studies for correlation of the second class of projects, dams, and channel improvements, could be accomplished without delaying the logical development of your program as a whole.

The foregoing observations are made because the importance of the proposed program is appreciated, and because of the responsibility of the Corps of Engineers in the field of flood control and of the Secretary of the Army for prescribing regulations for operation of flood storage provided by other agencies with Federal funds. The Corps of Engineers is in accord with programs of this kind for retardation of water flow and flood control on the smaller tributaries of a major river basin, when they are demonstrated to be sound from both engineering and economic standpoints, and you may be assured that the Corps of Engineers is desirous of further cooperation with you in reaching this objective. I appreciate the opportunity to review your report, and consider that it is an important contribution toward solution of the related problems of land and water control in the Brazos River Basin.

Sincerely yours,

LEWIS A. PICK,  
*Lieutenant General,  
Chief of Engineers.*

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LETTER FROM THE SECRETARY OF THE INTERIOR TO THE  
SECRETARY OF AGRICULTURE

DEPARTMENT OF THE INTERIOR,  
OFFICE OF THE SECRETARY,  
*Washington 25, D. C., September 7, 1951.*

Hon. CHARLES F. BRANNAN,  
*Secretary of Agriculture, Washington 25, D. C.*

MY DEAR MR. SECRETARY: In accordance with Federal Inter-Agency River Basin procedures, Assistant Secretary Hutchinson transmitted by letter, dated May 2, 1951, for the information and comments of the Department, copies of the Department of Agriculture's survey report on the Brazos River watershed, Texas.

The report recommends a program of runoff and water-flow retardation and soil-erosion prevention during a 15-year period in the Brazos River watershed in Texas, at an estimated total cost of \$109,065,000. Of this total amount, \$69,084,000 would be paid by the Federal Government, \$9,578,000 by non-Federal public agencies, and \$30,403,000, or its equivalent, by private interests. The recommended program includes the improvements proposed in previous interim reports on the Little River and the Bosque River watersheds which were both commented on by this Department by letters of December 22, 1950.

It is estimated on the basis of 1949 prices that the recommended program will yield an average annual flood-control benefit of \$5,690,000 and an average annual conservation benefit of \$25,345,000 accruing to farmers and ranchers of the affected area, or a total benefit of \$31,035,000 annually. The total annual cost is estimated to be \$12,796,000 and thus the over-all benefit-cost ratio is indicated to be 2.43 to 1 on the basis of 1949 prices. The report also contains an evaluation of benefits and annual costs based on an assumed future price level, which results in an indicated benefit-cost ratio of 2.28 to 1.

In accordance with Federal Inter-Agency procedures, the report has been reviewed by the field offices of the Fish and Wildlife Service, the Geological Survey, Southwestern Power Administration, and the Bureau of Reclamation. Opportunity for such field review is appreciated.

In our opinion this report is the best organized of any of those reviewed thus far and embodies the type of reporting recommended by the Department in previous comments on earlier Department of Agriculture reports. For example, the report gives adequate recognition of comments made by agencies reviewing the report at field level. It also contains appropriate acknowledgments of weather, stream flow, and topographic mapping data. Further, it includes an adequate bibliography.

The report contains sufficient detail as to methodology, as in the section on hydrology, to permit clear interpretation and understanding of the procedures used. It acknowledges that, "present knowledge provides no reliable means of computing with acceptable accuracy the change in total annual stream discharge to be expected on large watersheds as a result of the recommended measures." This is consistent with the views of this Department. The water cost or loss of water through nonbeneficial consumptive use of the recommended land treatment and soil conservation program is important in the Brazos River Basin. The report recognizes the effects of water-retardation structures on infiltration, increased base flow, increased evaporation losses, and other hydrologic factors. Since the water cost of the program may be excessive, it is recommended that an active project to determine the water cost of the recommended program be initiated promptly and prior to installation of the measures proposed so as to provide data to demonstrate the effects of the program.

Loss of water through nonbeneficial consumptive use is of vital importance to this Department. The report states that the base flow in streams will be increased by the application of the recommended measures and that proportionately this increase will be greater during periods of critically low flow. However, analysis of the effects of land-treatment measures on resultant water yield due

to increased evaporation and transpiration from plant and soil surfaces and to evaporation and seepage from stock ponds and water-retardation structures, by the Bureau of Reclamation and the United States Geological Survey in other areas, indicates that such losses may be very significant, causing a material reduction in water yield. Realistic planning for truly comprehensive basin development, which includes such features as flood control, irrigation, hydroelectric power, fish and wildlife conservation and recreation, requires firm evaluation of the effects of water-flow retardation and land-treatment programs upon water yield as early as possible.

The report also states that an estimate was made of the potential decrease in annual stream discharge due to evaporation from the permanent pools of the recommended floodwater retarding structures on Brazos River watershed, but that no allowance was made for seepage and the underground escape of water from the reservoirs. Data collected by the Bureau of Reclamation and the Geological Survey from stock ponds in certain northern areas indicate that seepage losses may amount to as much as three times the evaporation loss. This seepage loss may be completely lost to stream flow since it furnishes water to water-loving vegetation downstream from the reservoir and around the water surface. Therefore, we feel that seepage losses should not be ignored in evaluating the depletion of stream flow unless it can be demonstrated by actual field tests that such seepage losses are negligible. Other physical water spreading devices, such as terraces and field diversions, included under land treatment in the proposed program, may also tend to decrease the downstream supply.

The Department is quite interested in the estimates of future sedimentation rates in existing and proposed reservoirs. The report indicates that as a result of the recommended program the sedimentation rates into these reservoirs within the Brazos River will be reduced by some 25 to 60 percent. To our knowledge, such reduction in sediment yield rates has never been measured for large areas where land treatment programs are being practiced. While the rates of soil erosion may be reduced to the degree indicated in the report as a result of the proposed program, the sediment yield rates into reservoirs may not be reduced proportionately. For example, in some instances a large portion of the sediment load carried by flood flows in major streams is derived from bank cutting and channel degradation in tributary flood plains and alluvial fans. It is questionable whether or not the proposed land treatment measures will have an immediate effect upon sediment of this origin that will be readily manifest in reduced reservoir sedimentation rates to the degree anticipated by the proposed report.

Since the conservation benefits amount to approximately 82 percent of the total benefits it appears that this is essentially a project whose major features are essentially the same as the normal program of the Department of Agriculture for conservation farming, the benefits of which are dependent largely on increased crop yields and land values. The total average annual benefits of \$26,689,000 from the land treatment measures are obtained at a total average annual cost of \$11,352,000. The average annual conservation benefit of \$25,340,000 results entirely from the land treatment measures. The benefit-cost ratio of this phase of the program is 2.35 to 1.



The average annual benefits of \$5,690,000 which accrue from reduction in floodwater and sediment damage are actually about 18 percent of the benefits from the entire program. Most of the cost and benefit included under the heading "Independent measures" are represented by the probable construction of 555 floodwater retarding structures having an average storage capacity of 1,043 acre-feet each. Each of these floodwater retarding structures controls an average drainage area of 7.9 square miles. Total average annual cost of these floodwater retarding structures is \$1,281,000, and the total average annual benefit is \$4,033,000, yielding a benefit-cost ratio of 3.15 to 1. The remainder of the cost and benefit from "Independent measures" accrues from floodway and channel improvements at an average annual cost of \$163,000 with an average annual benefit of \$313,000. Of the total average annual flood-control benefits of \$5,690,000 accruing from a reduction in floodwater and sediment damage, \$4,346,000 is obtained from the independent measures consisting of floodwater retarding structures and floodway and channel improvement works.

The presentation regarding maintenance costs of the program should be clarified. The main report states that local interests are expected to operate and maintain the recommended program, after it has been fully installed, at an estimated annual cost of \$9,552,000 or its equivalent. However, on page 129, appendix V, the following statement appears:

Maintenance of practices and measures on non-Federal land is considered the primary responsibility of local or private interests. The estimated costs thereof are presented in the report as non-Federal, but it is recognized that the Department of Agriculture has responsibilities to see that the maintenance is carried out to the extent that the going programs of the Department cannot adequately meet these requirements of maintenance. The Secretary may request funds under appropriate authorities for carrying out maintenance of these measures and practices.

This statement raises a serious question as to the extent to which the Federal Government will be called upon to aid in maintaining this proposed program. It would be helpful if the report set forth the policy of your Department regarding the responsibilities of local interest in such matters.

A preliminary draft of this report, dated September 1950, was received and favorable comments were transmitted to Regional Director Louis P. Merrill of the Soil Conservation Service by the Southwestern Power Administration in their letter of October 23, 1950. The Southwestern Power Administration is interested in the development of hydroelectric power and the distribution and sale of electricity to public bodies and cooperatives. In discharging this interest, the report has been reviewed by that Administration with a view toward the maximum development of hydroelectric power. The Department endorses the suggestion of the Southwestern Power Administration that this proposed program might be integrated with the Corps of Engineers' plan so that the benefits derived from the water-flow retardation program could be utilized to reduce the storage required for flood control and release that storage for allocation to other water uses.

The comments of the Fish and Wildlife Service have been set forth in a letter dated October 26, 1950, from the regional director to the regional director of the Soil Conservation Service in Fort Worth, Tex. In addition to those comments, we wish to point out that the floodway

and channel improvements proposed for some 81 miles of streams will have no effect on existing fishery resources due to the intermittent nature of flows in these streams. Further, we desire to reemphasize the desirability of manipulating features of the proposed program, consistent with its primary purposes, to realize the great potential benefit that could accrue to the fish and wildlife resources of this basin. Therefore, the Department requests that the Fish and Wildlife Service and the Texas Game, Fish, and Oyster Commission be permitted to actively participate in further detail planning and development of the proposed program.

Information obtained from the Bureau of Mines reveals that the measures recommended in the proposed program will be beneficial to the mineral industry.

In summary, we wish to commend your Department for the clarity of the presentations in this report. Our comments have been directed toward aiding you and other reviewing officials in making an objective analysis of the proposed program. We are somewhat apprehensive about the possibility for nonbeneficial consumptive use of water, which could result from some of the measures proposed, and would be a detriment to existing and proposed irrigation projects. We strongly urge a program for the evaluation of the effects of these proposed water-flow retardation and soil-erosion prevention measures. The Geological Survey and Bureau of Reclamation of this Department would be pleased to cooperate with agencies of your Department in carrying out such a program. Finally, the Fish and Wildlife Service and the Texas State Game and Fish Commission should be given the opportunity to participate in the preparation of work plans for the proposed program in order to realize the maximum fish and wildlife conservation benefits consistent with the primary purposes of the recommended program.

Opportunity for review of this report is appreciated.

Sincerely yours,

OSCAR L. CHAPMAN,  
*Secretary of the Interior.*

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LETTER FROM THE FEDERAL SECURITY AGENCY TO THE  
SECRETARY OF AGRICULTURE

FEDERAL SECURITY AGENCY,  
PUBLIC HEALTH SERVICE,  
*Washington 25, D. C., August 1, 1951.*

DEAR MR. SECRETARY: Pursuant to the policies and procedures established by the Federal Inter-Agency River Basin Committee, we have reviewed the preliminary report furnished by your Department entitled "Survey Report Brazos River Watershed, Texas," dated January 1951.

The only comments we have concerning this report are—

1. It is recommended that prior to construction the local health authorities be contacted to determine if construction will meet State sanitary code requirements particularly as they apply to mosquito breeding.



2. If possible, it is suggested that the report give some information as to the effect the proposed program will have on minimum stream flows.

Sincerely yours,

M. D. HOLLIS,  
*Chief Sanitary Engineering Officer, PHS,  
FSA Member, Federal Inter-Agency River Basin Committee.*

HON. CHARLES F. BRANNAN,  
*The Secretary of Agriculture, Washington 25, D. C.*

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LETTER FROM THE FEDERAL POWER COMMISSION TO THE SECRETARY OF AGRICULTURE

FEDERAL POWER COMMISSION,  
*Washington 25, D. C., July 16, 1951.*

Subject: Brazos River watershed, Texas.

HON. CHARLES F. BRANNAN,  
*Secretary of Agriculture, Washington 25, D. C.*

DEAR MR. SECRETARY: The comments herein relative to your Department's survey report on the Brazos River watershed, Texas, are made in response to the Assistant Secretary's letter of May 2, 1951. The transmittal of these comments is in accordance with established procedures of the Federal Inter-Agency River Basin Committee.

The survey report recommends a program of runoff and water-flow retardation and soil-erosion prevention for the Brazos River Basin consisting of various adjustments in land-use practices, channel improvements, upstream retarding structures, and other measures. The program would be developed over a period of 15 years at an estimated total cost of \$109,065,000, of which \$69,084,000 would be borne by the Federal Government, \$9,578,000 by non-Federal public agencies, and \$30,403,000 by private interests. Based on future price and cost levels assumed to prevail under an intermediate level of employment, the report estimates the ratio of average annual benefits to average annual costs to be 2.28 to 1.

It is noted that the program recommended in the subject report encompasses the programs previously recommended by your Department in separate interim reports on the watersheds of the Bosque and Little Rivers, two principal tributaries of the Brazos River. The Commission, in its letters of November 1, 1950, and November 6, 1950, respectively, on these interim reports, commented on the proposed improvement of the two watersheds and expressed the opinion that the programs would have little or no effect on hydroelectric power in the basins, and stated that there were no possibilities for the development of power in connection with the proposed improvements.

The Commission staff has reviewed the survey report of your Department on the Brazos River watershed with the primary object of ascertaining whether or not the recommended plan of improvement would affect existing or potential hydroelectric plants or would afford opportunities for the development of hydroelectric power. The only existing hydroelectric plant in the basin is the Possum Kingdom pro-

ject, under license of the Federal Power Commission, with 22,500 kilowatts installed. The aggregate installed capacity at the undeveloped water-power sites in the basin is presently estimated to be about 200,000 kilowatts. It is the opinion of the staff that these existing and potential power developments would probably derive some benefit from possible increases in low water flows and from decreases in the rate of sedimentation of reservoirs as a result of the measures recommended in the survey report. The staff reports that your Department's program does not present opportunities for developing hydroelectric power at the proposed water-retarding structures or in conjunction with the other proposed improvements.

Based upon its consideration of the report of your Department and on the studies by its own staff, the Commission concludes that the recommended program would have but slight effect on hydroelectric power development, although the over-all net effect would probably be beneficial. The Commission concludes further that there are no possibilities for the development of power in connection with the improvements proposed in your Department's program for the Brazos River watershed.

Sincerely yours,

MON C. WALLGREN, *Chairman.*

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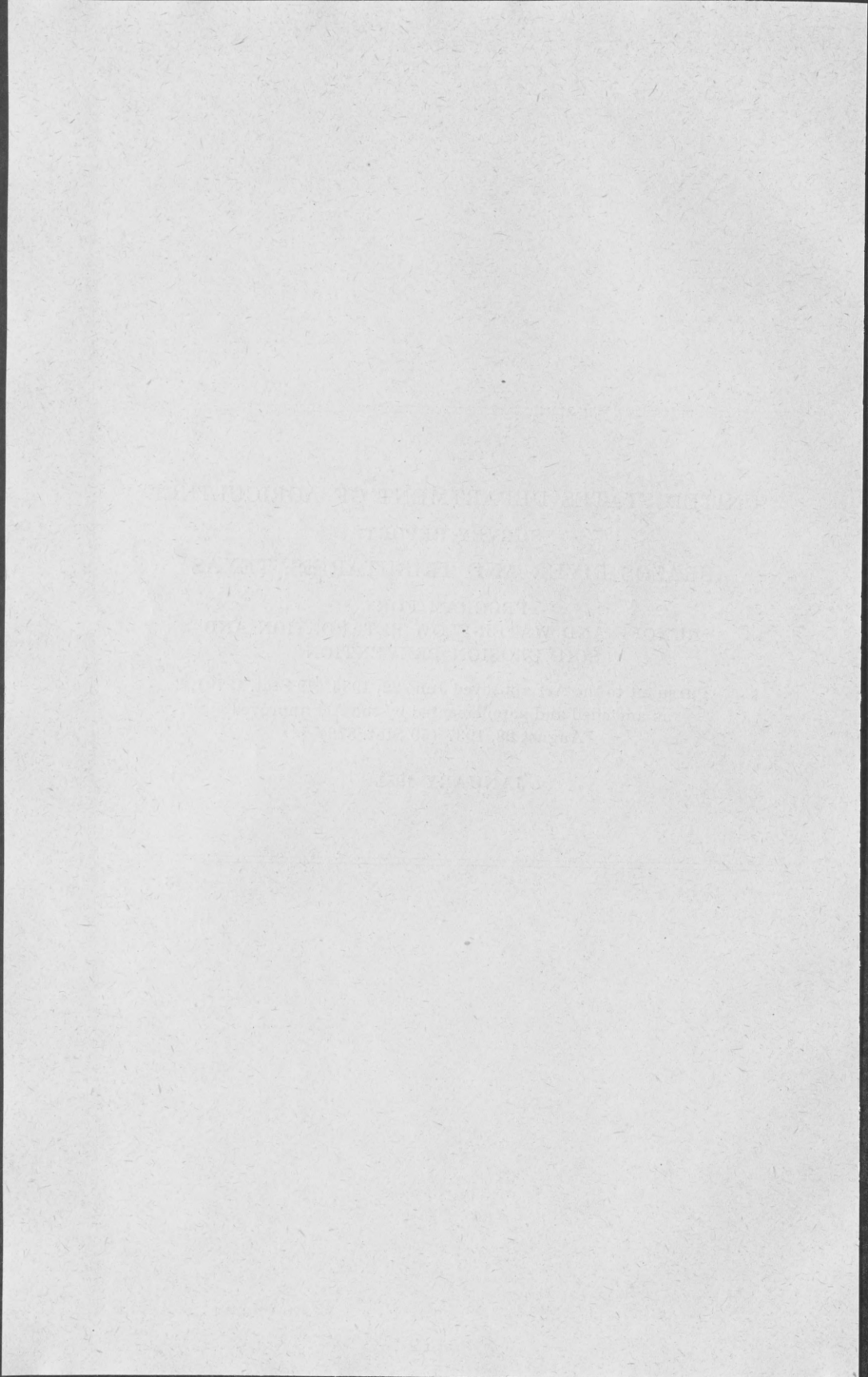
UNITED STATES DEPARTMENT OF AGRICULTURE  
SURVEY REPORT  
BRAZOS RIVER AND TRIBUTARIES, TEXAS  
PROGRAM FOR  
RUNOFF AND WATER-FLOW RETARDATION AND  
SOIL EROSION PREVENTION

Pursuant to the Act approved June 22, 1936 (49 Stat. 1570),  
as amended and supplemented by the Act approved  
August 28, 1937 (50 Stat. 876)

JANUARY 1951

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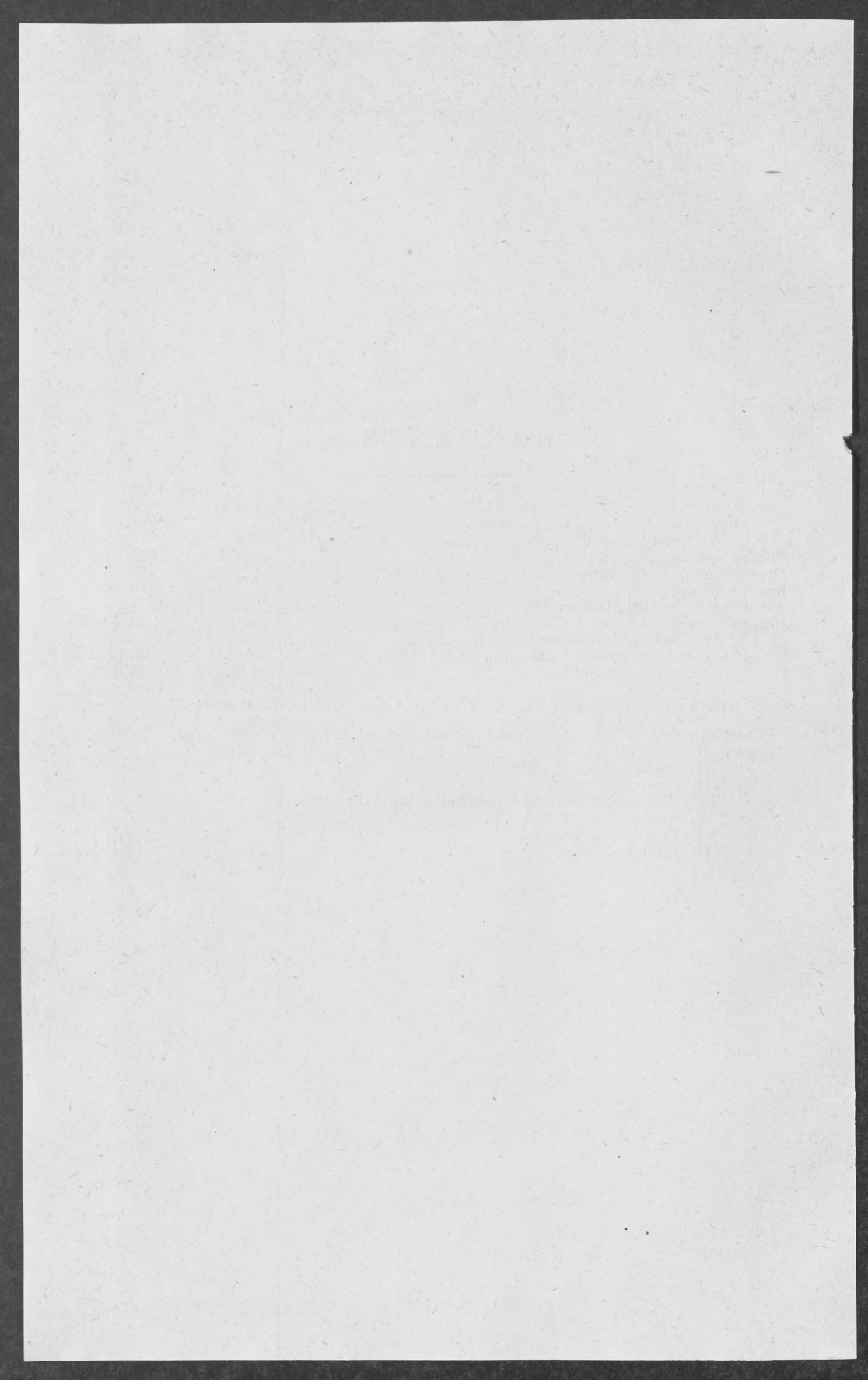
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### LIST OF APPENDIXES MADE IN CONNECTION WITH THE REPORT

These appendixes are not printed in this document.

- Appendix I. Physical factors.
- II. Land and water economy.
- III. Hydrology.
- IV. Watershed flood problems and related damages.
- V. Recommended program.
- VI. Program appraisal.
- VII. Bibliography.



# BRAZOS RIVER WATERSHED, TEXAS

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## INTRODUCTION

*Authority.*—This survey report is submitted under the provisions of the act approved June 22, 1936 (49 Stat. 1570), as amended and supplemented.

*Purpose and scope of report.*—The purpose of this report is to outline a program of runoff and water-flow retardation and soil-erosion prevention for the watershed of the Brazos River in Texas, and to present recommendations for installing and maintaining the program, together with an analysis of its cost and benefit. The area considered contains 41,997 square miles.

## RECOMMENDATIONS

It is recommended that a program of runoff and water-flow retardation and soil-erosion prevention be installed during a 15-year period in the Brazos River watershed in Texas at an estimated cost of \$69,084,000 to the Federal Government, at an estimated cost of \$9,578,000 to other public agencies, and at an estimated cost of \$30,403,000 or its equivalent<sup>1</sup> to local interests, making an estimated total cost of \$109,065,000 for the installation of the recommended program.

The estimated annual cost to local interests of operating and maintaining the recommended program, after it has been fully installed is \$9,552,000 or its equivalent. Of this amount \$9,355,000 or its equivalent will be expended by landowners and operators for maintaining land-treatment measures and for the increased cost of operating a more profitable system of conservation farming and \$189,500 will be expended by a local agency or agencies acceptable to the Secretary of Agriculture for operating and maintaining those installations which are not considered a part of farm and ranch operations. The Federal Government will expend \$7,500 for operating and maintaining a system of fire protection.

The program herein recommended includes the intensification, acceleration, and adaptation of certain activities under current programs of the Department of Agriculture, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and water-flow retardation and soil-erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out this program. Although the current activities of the Department primarily related to the Flood Control Act are not included in the program herein specifically recommended, this program is based on the continuation of such current activities at least at their present level.

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<sup>1</sup> Labor, materials, equipment, land easements, rights-of-way, and other contributions in lieu of cash payments.

The interdependent measures which will accomplish the desired objectives of reducing floodwater and sediment damage and conserving soil and water resources are as follows: Construction of terraces on sloping cultivated land, construction of field diversions, application of cover crops and other cropland conservation measures on cultivated land, construction and vegetation of farm and group waterways, stabilization of gullies, establishment of new grassland, improvement and management of existing grassland, fire protection, construction of floodwater retarding structures and floodway and channel improvements.

Technical services will be made available for planning and applying the necessary land use adjustments, for planning and applying land treatment measures on farm and ranch lands and for integrating the measures included in the recommended program. Educational assistance will be provided to facilitate the installation of the recommended program.

The Secretary of Agriculture may construct such buildings and other improvements as are needed to carry out the measures included in the recommended program.

The Secretary of Agriculture may make such modifications or substitutions of the measures described in this report as may be deemed advisable on account of changed physical or economic conditions or improved techniques, whenever he determines that such action will be in furtherance of the objectives of the recommended program.

The authority of the Secretary of Agriculture to prosecute the recommended program shall be supplemental to all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

It is estimated that the recommended program will yield an average annual flood-control benefit of \$5,690,000.<sup>2</sup> In addition to this flood-control benefit, an estimated average annual benefit of \$25,345,000,<sup>2</sup> from conservation farming and ranching will accrue to landowners and operators in the watershed.

The ratio of the estimated average annual benefit to the estimated average annual value of the total cost of the recommended program is 2.28 to 1.<sup>3</sup>

It is anticipated that the recommended measures will be installed under cooperative arrangements with soil conservation districts, State and local governments, or other agencies acceptable to the Secretary of Agriculture.

#### DESCRIPTION OF THE WATERSHED

The Brazos River in Texas flows into the Gulf of Mexico near Freeport, about 640 miles southeast of its source in the high plains of New Mexico. In Texas the watershed has an area of 41,997 square miles. The maximum width of the watershed is about 120 miles.

The Brazos River is formed by the junction of the Salt Fork and the Double Mountain Fork near Aspermont. Both streams have

<sup>2</sup> 1949 prices.

<sup>3</sup> Based on future price and cost levels assumed to prevail under an intermediate level of employment.



their source in the depression ponds of the high plains and are relatively small as they flow down into the rolling red plains. The Brazos River is joined by the Clear Fork, Palo Pinto, and Paluxy Creeks, Bosque River, Little River, Yegua Creek, Navasota River, Mill Creek, and numerous minor creeks and branches as it flows toward the Gulf of Mexico.

The Brazos River watershed is a cross section of Texas. The river flows across nine conservation problem areas which reach across the watershed. From the featureless cultivated high plains in the west the river enters the rolling red plains where some rolling sandy clay farm lands are found on interstream divides. The largest percentage, however, is composed of rough shallow-soil hillsides and broken valleys bordering the deeply incised, sand-bedded streams which are dry most of the year. The river traverses a smooth, shallow-limestone, grassland ridge extending into the watershed from the south and enters the mixed sandstone, limestone, and shale ridge country of the Reddish Prairies. Here the valleys are flat, surrounded by abrupt wooded slopes used for grazing. Soils are diverse and generally of low value, being either of heavy intractable clays or loose and sandy material. At the eastern edge of this area the river enters the dissected shallow limestone plateau of the Grand Prairie. This is a valuable and extensive grazing area with some cultivated heavy clay areas on the smooth divides and in the alluvial valleys.

As the river enters the blackland prairie, an area of deep black cultivated land, the main valley widens and the alluvial plain is intensively cultivated to the coast prairie area. Tributary valleys are wide and usually cultivated except where channels are choked with sediment causing frequent overflows. Below the mouth of the Little River is the forested Coastal Plains, a rolling wooded area of sandy soils and occupied by small general farms. Near Bellville the river enters the flat coast prairie and flows through a narrow belt of coastal marsh bordering the Gulf of Mexico. In the small area of coast prairie the soils are deep and fertile and used for rice production.

The economy of the watershed is rural. Since settlement started in the east and spread westward farming and ranching have predominated in the area. Petroleum production, coal, and sulfur mining, cement manufacture, quarrying of building stones, sand and gravel stripping, and ceramics are important. About 96 percent of the land area is in farms and ranches and over 50 percent of the units are owner-operated.

Approximately 42 percent of the entire watershed is in cropland, 45 percent is in open grassland, 7 percent is in pastured woodland, and 6 percent in miscellaneous uses. A large percentage of the western area is subject to prolonged droughts and severe wind and water erosion. The grassland areas are unimproved and commonly overgrazed.

From 1930 to 1940 the farm population declined 12 percent, and the trend continued during the war years of 1941-45. In 1940 the total population was about 1,040,000, of which 68 percent was classed as rural.

Annual rainfall in the watershed ranges from about 16 inches in the extreme western area to 47 inches near the coast. About three-fourths of this rainfall occurs during or immediately preceding the growing season.

## FLOOD PROBLEMS

Eleven major floods have been recorded on the main stream of the Brazos River during the period 1899-1944. The majority of these occurred during the spring growing season while only two occurred during the winter months. Floods on the tributaries are more numerous but usually do not cause the main river to flood.

Floods are usually caused by two types of storms: (1) General storms, and (2) thunderstorms. The general storms originate either in the Gulf of Mexico or in the southwestern highlands, usually cover a large portion of the watershed, and may cause major or widespread flooding of tributaries and the main stream. The thunderstorms are often characterized by intense precipitation over relatively small areas, and frequently cause severe local damage but contribute little to major floods.

Crop and pasture damage constitutes 71 percent of all floodwater and sediment damage in the watershed. The flood damages occurring on the main stream of the Brazos River below Possum Kingdom Reservoir were not evaluated except in cases where the damage was caused by the overflow of a tributary stream on the Brazos River bottom.

Damaging valley sedimentation occurs chiefly in the headwaters of the Leon River, Bosque River, and Paluxy Creek. Approximately 129,000 acres of cultivated and pasture lands of the alluvial plain have been seriously damaged by sediment deposition. Certain reaches in the Little River, Brushy Creek, Tehuacana Creek, Pond Creek, Big Creek, Yegua Creek, Navasota River, and Mill Creek, particularly in the upper watersheds, have suffered diminished channel capacities through sedimentation, thereby impairing drainage and increasing the frequency and severity of flooding. Scouring of the inundated farm lands by rapid floodwaters has seriously damaged many acres in the larger cultivated bottomland areas in the central part of the watershed.

The annual rates of storage capacity loss by sedimentation are relatively low in most reservoirs of the watershed. Possum Kingdom is losing 1 percent and Lake Waco 2.06 percent of storage capacity annually.

The estimated annual rates of capacity loss by sedimentation in the conservation and dead storage pools of the recommended and authorized reservoirs are as follows:

	Percent		Percent
Lake Waco.....	0.60	Lampasas.....	0.60
Whitney.....	.30	Lanesport.....	2.40
Proctor.....	2.90	Somerville.....	.50
Belton.....	.20	Ferguson.....	.60

Other damages which were considered but not evaluated in monetary terms include loss of life, insecurity of property and income, disruption of public service, damage to recreation and fish and wildlife, and costs of relief and sanitation.

Table 1 lists the monetary evaluation of the average annual floodwater and sediment damage in the Brazos River watershed.

TABLE I.—*Estimated average annual monetary damage (1949 prices), Brazos River watershed*

Type of damage:		
Floodwater damage:		
Agricultural and nonagricultural:		
Crops and pasture-----	\$10,304,000	
Other agricultural-----	1,586,000	
Nonagricultural-----	372,000	
Subtotal-----		\$12,262,000
Land: Floodplain scour-----		349,000
Sediment damage:		
Deposition of infertile overwash-----	\$199,000	
Sedimentation of reservoirs-----	421,000	
Cost of water treatment-----	39,000	
Subtotal-----		659,000
Indirect damage-----		1,280,000
Total average annual damage-----		14,550,000

## ACTIVITIES RELATED TO FLOOD CONTROL

The Department of the Army, Corp of Engineers, has prepared a survey report<sup>4</sup> of the Brazos River and its tributaries which recommends the following:

(1) Whitney Reservoir: This reservoir is in process of construction on the Brazos River and will offer additional control of flooding on the main stream below Possum Kingdom Reservoir.

(2) Belton Reservoir: This reservoir is being constructed on the Leon River just above the Little River main valley and will offer considerable protection to that area and to the Brazos below its confluence with the Little River.

(3) Waco Reservoir: A reservoir is recommended which will engulf the present Lake Waco on the Bosque River. Flood damages on the Bosque below the reservoir will be nearly eliminated and damages on the Brazos River will be reduced.

(4) Proctor Reservoir: A reservoir is recommended on the Upper Leon which will greatly reduce the flood damages in the Leon River bottomlands. Proctor Reservoir will reduce the flood control storage requirements at the Belton Reservoir and permit reallocation of the excess flood control storage at Belton to conservation uses.

(5) Lampasas Reservoir: A reservoir on the Lampasas River above its junction with the Leon River will reduce flood damages on its lower reaches and on the Little and Brazos Rivers.

(6) Lanesport Reservoir: A reservoir is recommended on the San Gabriel River which will greatly reduce flood damages on a major cultivated bottomland area below the dam and reduce flooding on the Little and Brazos Rivers.

(7) Somerville Reservoir: This reservoir is recommended on Yegua Creek and will reduce flooding on the main stream of the Brazos River below. Flood heights below the reservoir will be considerably reduced.

(8) Ferguson Reservoir: This reservoir is recommended on the Navasota River and will reduce flooding on the lower part of the Navasota and Brazos Rivers.

<sup>4</sup> Report on Survey of the Brazos River and tributaries, Texas: Oyster Creek, Tex.; Jones Creek, Tex. U. S. Engineering Office, Galveston, Tex., August 1947.

(9) Local channel improvements to reduce flood damage are authorized on Mill Creek near Bellville and in the Leon River in the city of Eastland. A channel rectification project is also recommended in the city of Lampasas and levee improvements are recommended for Burleson County Improvement District No. 1 to reduce flood damages.

The effects of these improvements have been considered in this report. The damage and benefit evaluations were made on the assumption that each improvement was constructed and operating.

Two soil conservation demonstration projects, including nearly 180,000 acres, were established on Elm and Green Creeks in 1933 and 1935, respectively. Their purpose was to demonstrate the value of erosion control practices on farms within those areas. Conservation treatment of about 50 percent of the farmland was completed by 1940 and additional acreages have been treated since that time.

The Department of Agriculture, through its several agencies and in cooperation with State and local agencies, is currently assisting owners and operators of farm and ranch lands in the application of measures which are deemed of primary importance to the objectives of the Flood Control Act. Measures being installed on cropland include terraces, field diversions, establishment of farm and group waterways, grade stabilizing and waterflow or erosion control structures, proper crop rotations, cover crops, crop residue management, and contour farming. On grasslands or on lands being converted from cropland to grasslands the measures are grass seeding, the application of fertilizer for adequate growth and establishment of cover, proper management of grazing and the control of brush and weeds. The Department of Agriculture is expending approximately \$3,108,000 annually to assist in the application of these measures on the lands of the watershed.

The State of Texas operates through several of its departments and institutions to provide valuable conservation services to farmers, ranchers, municipalities and industries. This includes research (nine experiment stations) and the dissemination of research findings, educational activities and services. Recently the Bluebonnet ordnance plant at McGregor was transferred to the Texas Agricultural and Mechanical College for use in experimental work. Research on crops and livestock will be carried on within the 15,000-acre area located in the drainage area of the South Bosque River. Soil conservation districts (which include nearly 100 percent of the watershed) and other similar organizations perform valuable functions in the management of soil and water resources.

The Brazos River Conservation and Reclamation District, organized under State law, is active in the watershed. Its objective is to conserve and develop the water resources of the entire Brazos River watershed.

#### RECOMMENDED PROGRAM

The recommended program of runoff and water-flow retardation and soil-erosion prevention includes the following interdependent measures:

1. Construction of approximately 115,650 miles of terraces. These will be constructed on sloping farm lands to conduct excess rainfall at nonerosive velocities to protected outlets or waterways.



This measure will reduce the amount of sediment carried to streams by decreasing the length of unbroken slope. All terraced land will be cultivated parallel to the terrace.

2. Construction of approximately 2,990 miles of field diversions. these graded channels will be designed to divert runoff away from severely eroded or local high-damage areas. Their use will assist in the establishment of grassland and in the protection of cropland measures to be used for cover protection and erosion control.

3. Establishment of cover crops on approximately 193,100 acres of cropland. Cover crops will protect the soil from erosion and will increase the soil organic matter. These crops, used for green manures or as cash crops, will be grown in the normal cropping systems and will occupy approximately 20 to 25 percent of the cropland each year.

4. Application of cropland conservation measures as needed, either alone or in combinations. Treatment will vary from area to area depending upon physical conditions, and will be applied on about 1,852,290 acres. On land requiring some protection but not in need of terraces, contour farming will be practiced for water conservation. Improved rotations will be used to increase the water holding capacity of the soil and improve cover conditions. Crop residue management will be practiced to retard runoff, reduce erosion, and increase the rate of rainfall infiltration into the soil.

5. Shaping and stabilizing by vegetative control approximately 5,240 miles of farm and group waterways to reduce the amount of sediment and gulying resulting from the uncontrolled out-letting of terraces. Broad vegetated strips with minimum shaping will be used to spread and conserve the runoff from the terraced fields.

6. Stabilization of approximately 2,380 miles of gullies and channels, for waterflow and sediment control. Revegetation, shaping, drop structures and small earthfill dams, to reduce the uncontrolled gradient of channels, arrest head cutting and reduce the rate of discharge of runoff by natural or artificial controls will be used to control land damage and the amount of sediment resulting from erosion of the channels.

7. Establishment of new grassland on approximately 233,700 acres of cropland unsuited to continued crop use and idle cropland which has an inadequate protective cover. The areas will be seeded to adapted grass and legume mixtures, fertilized, fenced, and properly managed as pasture. The grass cover will protect the soil from continued erosion and will increase infiltration of rainfall.

8. Improvement and management of approximately 3,782,900 acres of existing grassland, including reseeding with adapted grass and legume mixtures to rapidly improve the protective vegetative cover. Brushy areas in the grasslands on which competition has resulted in an inadequate protective cover will be cleared of brush, seeded and managed to insure a heavy grass cover. The use of proper systems of grazing will permit optimum forage growth, build up the vitality of the grass, and promote soil binding root growth.

This will provide adequate seed for natural reseeding and provide cover to reduce runoff and protect the soil.

9. Fire protection for 500,000 acres of private woodlands in the forested Coastal Plains to increase infiltration and the water-holding capacity of the soil and to reduce erosion and sediment production.

10. Construction of approximately 555 floodwater retarding structures. These structures, by providing temporary storage of floodwaters from approximately one-third of the watershed, will reduce flood peak discharges in the floodplains below the structures.

11. Construction of approximately 81 miles of floodway and channel improvements on tributary streams to reduce floodwater and sediment damage. Channels which are inadequate in size have forced the retirement of high-producing floodplain land to grazing use or idleness. Floodwater retarding structures will reduce the peak flood flows, but the floodway or channel will require enlargement in order to carry releases from the structures and runoff from the uncontrolled area without flooding the entire floodplain too often for crop use.

Technical services will be made available for planning and applying the necessary land-use adjustments and land-treatment measures on the farms and ranches, and for integrating these measures with the other measures included in the recommended program. Educational assistance will be provided to facilitate the installation of the recommended program. Technical services, educational assistance, and other aids provided under this program will be directed toward furthering the specific objectives of floodwater and sediment damage reduction and will be fitted as to method and synchronization into subwatershed operations activities.

Provision will be made in selected segments of subwatersheds for the measurement of precipitation, runoff, ground-water recharge, and sediment loads of streams, to facilitate application of the recommended program.

#### COST OF RECOMMENDED PROGRAM

The estimated cost of installing the recommended program in the Brazos River watershed is shown in table 2. Of this cost it is estimated that the Federal Government will expend \$69,084,000, other public agencies will expend \$9,578,000 and private interests will contribute \$30,403,000.

The recommended program will be operated and maintained at an estimated annual cost of \$9,552,000 or its equivalent to local interests. Of this amount, it is estimated that \$9,355,000 will be expended by landowners for operating and maintaining land treatment measures and for the increased cost of operating a more profitable system of farming, and that \$189,500 will be expended by a local agency or agencies acceptable to the Secretary of Agriculture for operating and maintaining floodwater retarding structures and floodway and channel improvements. It is estimated that the Federal Government will expend \$7,500 annually for operating and maintaining a system of fire protection.

TABLE 2.—*Estimated cost of installing the recommended program, Brazos River watershed*

Measure	Unit	Quantity	Cost (1949 prices)
Terraces.....	Miles.....	115,650	\$21,036,000
Field diversions.....	do.....	2,990	1,229,000
Cover crops.....	Acres.....	193,100	990,000
Farm and group waterways.....	Miles.....	5,246	1,095,000
Gully stabilization.....	do.....	2,380	3,904,000
Establishment of new grassland.....	Acres.....	233,700	9,244,000
Improvement and management of existing grassland.....	do.....	3,782,900	25,930,000
Fire protection.....	do.....	500,000	150,000
Floodwater retarding structures.....	Each.....	555	42,666,000
Floodway and channel improvement.....	Miles.....	81	2,821,000
Total.....			<sup>1</sup> 109,065,000

<sup>1</sup> Of this amount 15.6 percent is for technical services, hydrologic studies to facilitate program installation, administration of direct aids, and educational assistance. Non-Federal public agencies will bear approximately one-half the cost of educational assistance and one-quarter of the cost of a system of fire protection.

#### BENEFITS FROM THE RECOMMENDED PROGRAM

The recommended program will reduce floodwater and sediment damages and increase crop production. It is estimated that the program will reduce floodwater damage to crops, grassland, and other agricultural property by approximately 35 percent, floodwater damage to land by approximately 36 percent, sediment damage by approximately 24 percent and indirect damage by approximately 29 percent. Other benefits will accrue from the more intensive use of floodplain lands made possible by the elimination of numerous small floods. Benefits in the form of increased crop and grassland yields will result from the installation of the land-treatment portion of the program.

The full attainment of the benefit evaluated in this report is dependent upon the cooperation and support of farm owners and operators and local agencies in installing and maintaining the recommended practices and measures.

The estimated average annual monetary benefit resulting from the recommended program for the Brazos River watershed is shown in table 3.

In addition to the monetary benefits, there will be unevaluated benefits such as reduction of loss of life and alleviation of illness, hardship and disease epidemics following flood disaster; increased food and improved shelter for wild fowl and game animals; a greater population of fish as a result of clearer streams of more even flow; and improved recreational facilities.

#### COMPARISON OF BENEFIT AND COST

The ratio of the estimated average annual benefit to the estimated average annual value of the total cost of the recommended program is 2.28 to 1. The ratio has been computed on the basis of future price and cost levels assumed to prevail under an intermediate level of employment.

TABLE 3.—*Estimated average annual monetary benefit from the recommended program (1949 prices), Brazos River watershed*

Source:

Reduction in floodwater damage:

Agricultural and nonagricultural:

Crops and pasture-----	\$3, 597, 000
Other agricultural-----	570, 000
Nonagricultural-----	141, 000

Subtotal----- \$4, 308, 000

Land: Flood-plain scour----- 125, 000

Reduction in sediment damage:

Deposition of infertile overwash-----	\$51, 000
Sedimentation of reservoirs-----	100, 000
Cost of water treatment-----	9, 000

Subtotal----- 160, 000

Reduction in indirect damage----- 373, 000

Intensified use of flood-plain lands: Increased income from the land----- 724, 000

Conservation benefit <sup>1</sup>----- 25, 345, 000

Total average annual benefit----- 31, 035, 000

<sup>1</sup> The benefit which accrues to the owners and operators of the land on which the recommended program is installed.